P.D.E.A's

Prof. Ramkrishna More Arts, Commerce, Science College

Akurdi Pune-411044

Affiliated to

Savitribai Phule Pune University [SPPU]

B.Sc. Honors Mathematics

(Four Years B.Sc, **Honors** Program)

Choice Based Credit System [CBCS]

Under

Autonomy and NEP-2020

2024 Pattern

From Academic Year
2026-2027

Syllabus

Graduate with Honors with Mathematics Major

Board of Studies in Mathematics

(Prof. Ramkrishna More College Akurdi Pune)

Rules and Regulations

1. **National Credit Framework (NCF):** For creditisation and integration of all higher education qualifications leading to a certificate/diploma/degree with **multiple entry and exit options**, college will refer to National Credit Framework (NCF) which encompasses the qualification frameworks for higher education, vocational and skill education and school education, namely National Higher Education Qualification Framework (NHEQF), National Skills Qualification Framework (NSQF) and National School Education Qualification Framework (NSEQF) respectively.

2. **Structure of Four years multidisciplinary UG Programme and Five Years Integrated Multidisciplinary Master's Degree Programme with Multiple Entry and Exit Options at Different Levels:**

   (i) Students will have the flexibility to enter four years multidisciplinary Under Graduate Programme in odd semesters and exit a programme after the successful completion of even semesters as per their future career needs.

   (ii) Students will get a Certificate after a One year programme (minimum 40 Credits), a Diploma after two years (minimum 80 Credits), a Bachelor's degree after three years (minimum 120 Credits), and a Bachelor's degree with Research or Honours after Four years (minimum 160 Credits).

3. **Qualification Type and Credit Requirements of Four Years Multidisciplinary Degree Programme with Multiple Entry and Exit Options:**

   Details of qualifications, minimum credit requirements, exit credit courses, year and semester are as under.

Level	**Qualification Title**	**Credit Requirements**		**Semester**	**Year**
		Minimum	Maximum		
4.5	UG Certificate	40	44	2	1
5.0	UG Diploma	80	88	4	2
5.5	Three Year Bachelor's degree	120	132	6	3
6.0	Bachelor's degree with Research/Honours with Major	160	176	8	4
7.0	Master's Degree	200	220	10	5
8.0	Ph.D	—	—	—	—-

(ii) An exit 6-credit bridge course(s) lasting two months, including at least 6-credit job specific internship/apprenticeship that will help the graduates acquire job-ready competencies required to enter the workforce will be an additional requirement for the award of the undergraduate Certificate/ Diploma/ three year Bachelor's Degree.

(iii) On exit, the students will have the option to re-enter the programme in the college, or in a different higher education institution. Re-entry at various levels for lateral entrants in academic programmes should be based on the earned and valid credits as deposited and accumulated in the Academic Bank of Credits (ABC) through Registered Higher Education Institutions (RHEI) and proficiency test records.

(iv) Eligibility for admission to the fourth year of four-year Honours with Research Degree Programmes as per UGC guidelines: Minimum CGPA of 7.5 or minimum 75 % at three-year degree.

(v) PG curriculum, as illustrated below, have flexibility a) One-year Post- Graduate Diploma (PGD), b) Two year Post-graduate Programme and c) 5 Years Master's degree programmes with multiple Entry and Exit options at different levels.

a) **Post-Graduate Diploma (PGD):** Programme duration- One year (2 semesters) after any bachelor's degree, min. 40 credits.

(i) UGC: 1-Year (2 semesters) Post-Graduate Diploma (PGD) after 3- years Bachelor's degree: Level 6.0

(ii) UGC: 1-Year (2 semesters) PGD after 4 years Bachelor's degree (Honors/ Research): Level 6.5

b) **Master's Degree:**
UGC: 2-Years (four semesters) Master's Degree after obtaining a 3- years Bachelor's degree, Minimum 40 credits/year, second year devoted entirely to research, PG – 2nd year: Level 6.5
OR
1-Year (two semesters) Master's Degree after obtaining a 4-year Bachelor's degree (Honours/Research): Minimum 40 credits: Level 6.5

c) **Level 8 represents Ph. D. Research Degree**.

d) **A 5-year Integrated Bachelor's and Master's programme shall have a minimum of 220 credits**.

e) **Master's and doctoral programmes, while providing rigorous research-based specialization, should also provide opportunities for multidisciplinary work, in academia, government, research institutions, and industry**.

4. **Lateral Entry/ Re-entry at higher Levels after exit from lower levels of four years multidisciplinary UG degree programme:**

(i) The credit points earned and accumulated shall be used to determine the eligibility for taking admission to various programs at multiple levels, subject to fulfilment of the broad principles laid down under NCrF.
Students who leave with a Certification, Diploma, or a Basic Bachelor's Degree will be eligible to re-enter the programme at the exit level to complete or progress to the next level through lateral entry mode. Depending upon the academic and physical facilities available, the State Universities/ Autonomous Colleges (Higher Education Institutions or HEI) may earmark specific seats/ intake for lateral entry into the second year/ third year/ fourth year of a four years multidisciplinary UG degree programme as approved by Professional Standard Setting Bodies (PSSB/Govt. of Maharashtra/ statutory council of affiliating University plus any consequential vacancies caused by exits to an ongoing programme (four-year Degree Programme and Integrated Master's or second year Master's). Lateral entry or Re-entry is open to those students if he/she has either –
(a) successfully completed the first year/second year/third year of the particular four years multidisciplinary degree programme in any ABC registered HEI with valid credits in ABC and re-entering into the second year/third year/fourth year, respectively of the same four years degree programme of any ABC registered HEI, within stipulated/ permissible period of years as decided by Statutory Councils of that HEI
OR
(b) Already successfully completed a multidisciplinary four-year first- degree programme and is desirous of and academically capable of pursuing another multidisciplinary four years first-degree programme in an allied subject.

(ii) A student will be allowed to enter/re-enter only at the odd semester. Re-entry at various levels for lateral entrants in academic programmes should be based on the earned and valid credits as deposited and accumulated in Academic Bank of Credits (ABC) through Registered Higher Education Institutions (RHEI) and proficiency test records. However, in terms of the admission eligibility

requirements, the student shall belong to the same faculty/ discipline in terms of Major Subject i.e., the Major subject of his earlier Programme and the Major subject of the new Programme for which he is seeking admission must be from the same faculty/discipline. Reservation for lateral entry will be executed as per the Government of Maharashtra norms.

5. **Distribution of Credits across Multidisciplinary Four Years Degree Program:**

(i) Four-year multidisciplinary degree programme with Honours/ Specialization Degree will have Internship and Core /Major Courses with a minimum of 22 credits per sem. in the Fourth Year.

(ii) Four-year multidisciplinary degree programme with Research will have Research Projects, Seminars, Dissertations and Internships with a minimum of 22 credits per Sem. in the Fourth Year.

(iii) Students shall select a **'Major or Core Subject/ Discipline' and a 'Minor Subject/Discipline' from the lists of various Subject Combinations and Options provided the Colleges**. In general, for the four years multidisciplinary bachelor's degree programme, the distribution of credits will be as follows:
(a) Disciplinary/interdisciplinary Major/ Core Subject (minimum of 68 credits)- Mandatory and Elective Courses
(b) Disciplinary/interdisciplinary Minor Subject (maximum of 22 credits)
(c) Skill based/Vocational studies corresponding to the Major/ Core Subject (8 credits)
Field projects/internship/apprenticeship/community engagement and service corresponding to the Major/ Core Subject (14-22 credits) with a maximum of six credits per Semester
(e) Generic/ Open Electives through Baskets of Elective Courses (12 credits)
(f) Ability Enhancement Courses including Languages, Literature and Environmental Studies (12 credits) In-built modules on the Indian Knowledge System (IKS) in Major/ Core Subject at Level 4.5 – 2 credits
(h) Value-based Education, Life Skills and Professional Ethics: Co- curricular Courses such as Sports and Culture, NSS/NCC and Fine/ Applied/Visual Arts (8 credits).
Student can earn some credits (SEC/VSC/GE/OE) in the form of online from-

(i) The National Skills Qualifications Framework (NSQF) organizes qualifications for Vocational and Skill Courses in a series of 8 levels based on professional knowledge, professional skills, core skills and responsibilities, in the increasing order of complexity and competency.

(ii) University Grants Commission (Credit Framework For Online Learning Courses through Study Webs of Active-Learning for Young Aspiring Minds) Regulations, 2021, **permits up to 40 per cent of the total courses being offered in a particular programme in a semester through the Online Learning Courses offered through the Study Webs of Active-Learning for Young Aspiring Minds (SWAYAM) platform**.

6. **Examination and Assessment Process:**

(i) The basic principle of the credit framework is that credits are a function of the successful completion of a program of study/ vocational education/ training and assessment. No credit can be earned by the student unless the student is assessed for the achievement of the desired competencies and outcome of a program.

(ii) Exit options are provided with certification, diploma and basic Bachelor's degrees to the students at the end of the second, fourth and sixth semesters of a four years multidisciplinary degree programme. Students will receive a Bachelor's degree with Honours/ Research on successfully completing of all eight semesters of the UG Program either at a stretch or with opted exits and re-entries. For the smooth success of four-year multidisciplinary degree programme with multiple

entry and exit systems, the examination mode will be based on the combination of innovative trends in formative (informal and formal tests administered during the learning process) and summative (evaluation of student learning at the end of an instructional unit) examination modes. This is in line with the UGC Report on 'Evaluation Reforms in Higher Educational Institutions (2019)'.

(iii) **Evaluation of each students in each course will be done as follows:**

a. Each theory or practical course will be of 2 credits = 50 mark

b. Internal evaluation 40 % weightage (20 mark)

c. External evaluation 60 % weightage (30 marks)

d. Students should secure 40% marks in each type of evaluation for successful completion of a course (student should secure at least 8 marks in internal and 12 marks in external evaluation).

(iv) **Evaluation Pattern**.

a. Internal evaluation - Two written test, each of 20 marks will be conducted i. e. two tests on two modules. 1st assignment after completing 6 weeks of teaching and 2nd on completion of 13th week of teaching. Question paper should be designed so that evaluation of CO, PO, PSO can be performed. 10 marks out of 20 will be assigned from these written tests. Remaining 10 marks will be assigned from other types of evaluation such as seminars, orals, poster presentation, open book challenging tests, surprise test, objective test on whole syllabus of the course (at least 40 questions of objective type must be designed), etc. for 5 marks at least two different types technique must be utilized.

b. External Evaluation - External evaluation will be done at the end of semester. For theory, 30 marks written examination will be conducted and time of examination will be 2-hours.

7. **Declaration of Results:**

(i) Declaration of result is based on the Semester Grade Point Average (SGPA) earned towards the end of each semester or the Cumulative Grade Point Average (CGPA) earned at the completion of all eight semesters of the programme and the corresponding overall alpha-sign or letter grades as given in Table 2. If some candidates exit at the completion of the first, second or third year of the four years Undergraduate Programmes, with Certificate, Diploma or Basic Degree, respectively, then the results of successful candidates at the end of the second, fourth or sixth semesters shall also be classified on the basis of the CGPA obtained in the two, four, six or eight semesters, respectively. Successful candidates at the end of the tenth semester of the integrated Master's Degree Programmes shall also be classified on the basis of CGPA obtained in the ten semesters of the Programmes. Likewise, the successful candidates of one year or two semesters Master's Degree Programme are also classified on the basis of the CGPA of two semesters of the Master's Degree Programme. **Table-2: Grades on degree certificate/mark sheet will be assigned to the students as per the following table**

Semester GPA/ Program CGPA Semester/Program	% of Marks	Alpha-Sign / Letter Grade Result
9.00-10.00	90-100	O (outstanding)
8.00 - ¡9.00	80.00 – ¡90.00	A+ (Excellent)
7.00 - ¡8.00	70.00-¡80.00	A (Very Good)
6.00 - ¡7.00	60.00-¡70.00	B+ (Good)
5.50 - ¡6.00	55.00-¡60.00	B (Above Average)
5.00 - ¡5.50	50.00-¡55.00	C (Average)
4.00 - ¡5.00	40.00-¡50.00	P (Pass)
Below 4.00	¡ 40	F (Fail)
Ab	———	Absent

(ii) A student obtaining Grade F shall be considered failed and will be required to reappear in the examination. For non-credit courses 'Satisfactory' or "Unsatisfactory' shall be indicated instead of the letter grade and this will not be counted for the computation of SGPA/CGPA.

8. **Award of Major and Minor Degree:**

(i) A student pursuing four-year multidisciplinary UG programme will be awarded an appropriate Honours/ Research degree in Major/ Core Subject on completion of VIII Semester with the minimum of 176 credits if he secures in that Subject at least 50% of the total credits for that programme. He shall thus study the specific number of Mandatory Core Courses, Core Electives, Vocational and Skill Courses and Field projects/ Internships connected to Core Subjects in eight semesters so as to cover at least 50% of the total credits.

(ii) In case of Research Degree, a student shall pursue research project and write dissertation in that Major in the VII and VIII semesters.

On the basis of above rules and regulations under NEP-2020 following course frame work is adopted by the Prof. Ramkrishna More Arts, Commerce and Science College, Akurdi, Pune- 411044 for the completing of four years honours degree in Major and Minor subjects.

9. **Distribution of Credits across Four Years Degree Programmes:** In general, for the four years' bachelor's degree programme, the distribution of credits will be as follows:
(a) Major (Core) Subject comprising Mandatory and Elective Courses:

i. Minimum 50% of total credits corresponding to Three/Four - year UG Degree- Mandatory Courses offered in all Four years;

ii. 2 credit course on Major Specific IKS shall be included under Major;

iii. Elective courses of Major will be offered in the third and/or final year.

iv. Vocational Skill Courses, Internship/ Apprenticeship, Field Projects, Research Projects connected to Major first to fourth year.
(b) Minor Subject: 18-20 Credits

i. The Minor subjects may be from the different disciplines of the same faculty of DSC Major (Core) or they can be from different faculty altogether.

ii. The credits of Minor subjects shall be completed in the first three years of UG Programme.

(c) Generic/ Open Elective Courses (OE): 10-12 credits

i. It is to be offered in I and/or II year

ii. Faculty-wise baskets of OE shall be prepared by University/ Autonomous Colleges.

iii. OE is to be chosen compulsorily from faculty other than that of the Major.

(d) Vocational and Skill Enhancement Courses (VSEC): 14-16 credits Vocational Skill Courses (VSC): 8-10 credits, including Hands on Training corresponding to the Major and/or Minor Subject:

i. To be offered in first to three years; Wherever applicable vocational courses will include skills based on

ii. advanced laboratory practical of Major

(e)Skill Enhancement Courses (SEC): 06 credits

i. To be offered in I and II year;

ii. To be selected from the basket of Skill Courses approved by University/ Autonomous Colleges

(f) Ability Enhancement Courses (AEC), Indian Knowledge System (IKS) and Value Education Courses (VEC): 14 Credits

- **AEC: 08 credits**

i. To be offered in I and II year

ii. English: 04 Credits

iii. Modern Indian Language: 04 credits

iv. To be offered from the Basket approved by the College; The focus for both languages should be on linguistic and communication skills.

- **IKS: 2 Credits**

i. To be offered in I Year

ii. Courses on IKS to be selected from the basket of IKS courses approved by the Colleges

- **VEC: 04 Credits**

i. To be offered in I year

ii. Value Education Courses (VEC) Environmental Science Education (Compulsory), Understanding India, and Digital and Technological Solutions.

(g) Field Projects/ Internship/ Apprenticeship/ Community Engagement and Service corresponding to the Major (Core) Subject, Co-curricular Courses (CC) and Research Project

- Internship/Apprenticeship corresponding to the Major (Core) Subject: 8 Credits
- Field Projects/Community Engagement and Service corresponding to the Major (Core) Subject: minimum 4-6 credits
- To be offered in II, and III years of UG Degree Programmes.
- Co-curricular Courses (CC) such as Health and Wellness, Yoga education sports, and fitness, Cultural Activities, NSS/NCC and Fine/ Applied/ Visual/ Performing Arts: 8 credits. To be offered in I and/or II year

(f) Research Projects: 12 credits

To be offered in the final year for 4-year Honours with Research UG Degree The UGC Regulations, 2021 permit up to 40% of the total courses being offered in a particular programme in a semester through the Online Learning Courses offered through the SWAYAM platform and/or other State Level Common Platforms which can be developed in due course with the participation of different Universities/ HEIs.

Abbreviations:

Generic/ Open Electives: GE/OE; Vocational Skill and Skill Enhancement Courses: VSEC; Vocational Skill Courses: VSC; Skill Enhancement Courses: SEC; Ability Enhancement Courses: AEC;

Indian Knowledge System: IKS; Value Education Courses: VEC; OJT: On Job Training: Internship/ Apprenticeship; Field projects: FP; Community engagement and service: CEP; Co-curricular Courses: CC; Research Methodology-RM; Research Project: RP

Note: The Credit Distribution Table given above is illustrative only. The Universities/ Autonomous Colleges may suitably modify within the broader framework of credit distribution across six verticals.

10. **Graduate and Honors Degree Course Framework under Autonomy as per NEP-2020 Science If not mentioned, each proposed course (theory/practical) is of 2 credits**.

Sem	Major Courses	Major Elective Courses	Minor Courses	FP/OJT/CEP	Total Credits
I	(5×2C)T, 2×2C(T/P)	2T+2T/P	RM 4-Credits (T)	0	**22- Credits**
II	(5×2C)T, 2×2C(T/P)	2T+2T/P	0	OJT(4 Credit) (P)	**22- Credits**
III	(4+4+2)T,(2+2)T/P	2T+2T/P	0	RP-I(4 credits)P	**22- Credits**
IV	(4+4+2)T,(2)T/P	2T+2T/P	0	RP-II(6 credits)P	**22- Credits**

C- Credits;
RM – Research methodology;
RP - Research Project; OJT – On Job training;

Definitions:
1. One semester = 15 weeks.
2. 1-credit theory = 15 hours i.e. for 1 credit, 1 hour per week teaching is to be performed. 15 hours of 1-credit are splinted as 12 hours actual teaching + 3 hours Tutorial (practice problem solving sessions, repeated discussion on difficult topics, discussion on student's difficulties, questions discussion and internal evaluation)
1-credit practical = 30 hours. Thus, 1 credit practical = 2 contact hours in laboratory.
3. per week. 30 hours splinted as 24 hours actual table work and 6 hours for journal competition, oral on each practical and other internal evaluation.
4. Each theory course of any type (major, minor) is of 2 credits.
a. Theory per semester: Contact hours = 24 teaching + 6 tutorials (problem solving sessions, repeated discussion on difficult topics, difficult solution, questions discussion and internal evaluation)
b. Each course will be of two modules, One module = 15 hours
c. Each module may consist of one or more than one chapter.
5. Each practical course of any course is of 2 credits = 60 hours per semester
a. Minimum 12 laboratory sessions will be conducted in one semester.
b. Each laboratory sessions will be of 4 hours.

Structure of the course B. Sc. Honors Mathematics:

Major, Major Elective, Minor and OJP Courses

Sem	Course Type	Course Code	Generic Name	Title of the Course	Credits	No. of Hours /Practical to be conducted
VII	Major	MTMAT-471	Mathematics theory paper-19	Linear Algebra	2	30
		MTMAT-472	Mathematics theory paper-20	Group Theory	2	30
		MTMAT-473	Mathematics theory paper-21	Advanced Calculus	2	30
		MTMAT-474	Mathematics theory paper-22	Ordinary Differential Equations	2	30
		MTMAT-475	Mathematics theory paper-23	Financial Mathematics-I	2	30
		MTMAP-476	Mathematics practical paper-9	Practical on Linear Algebra and Group Theory	2	12
		MTMAP-477	Mathematics practical paper-10	Practical on Advanced Calculus and Financial Mathematics-I	2	12
	Major Elective	MTMET-471A	Mathematics Elective theory paper-5	Python Programing	2	30
		MTMET-472A	Mathematics Elective theory paper-6	Dynamical System	2	30
		MTMEP-471B	Mathematics Elective practical paper-5	Practical on Python Programming	2	12
		MTMEP-472B	Mathematics Elective practical paper-6	Practical on Dynamical System	2	12
	RM	MTRMT-471		Research Methodology	2	30
	RM	MTRMP-472		Research Methodology	2	12
VI	Major	MTMAT-481	Mathematics theory paper-24	Number Theory	2	30
		MTMAT-482	Mathematics theory paper-25	Ring Theory	2	30
		MTMAT-483	Mathematics theory paper-26	Measure and Integration	2	30
		MTMAT-484	Mathematics theory paper-27	Partial Differential Equations	2	30
		MTMAT-485	Mathematics theory paper-28	Integral Equations	2	30
		MTMAP-486	Mathematics practical paper-11	Practical on Number Theory and Ring Theory	2	12
		MTMAP-487	Mathematics practical paper-12	Practical on Measure and Integration and Partial Differential Equations	2	12
	Major Elective	MTMET-481A	Mathematics Elective theory paper-7	Financial Mathematics-II	2	30
		MTMET-482A	Mathematics Elective theory paper-8	Advanced Complex Analysis	2	30
		MTMEP-481B	Elective Mathematics practical paper-7	Practical on Financial Mathematics-II	2	12
		MTMEP-482B	Elective Mathematics practical paper-8	Practical on Advanced Complex Analysis	2	12
	OJT/FP	MTOJP-481		On Job Training	4	60

Program Outcomes:

PO1: Knowledge: The learner is encouraged to use various mathematical methods (analytical and numerical) and experimental methods as an application to the acquired concepts and principles that help in studying various branches of sciences.

PO-2: Problem Analysis: Well equipped with an understanding of the analytical methods involved, they are in a position to interpret and analyse results obtained from experiments and draw suitable conclusions against their supported data acquired.

PO-3: Designing Solutions: Having acquired knowledge of mathematical subjects, students are trained to think out of the box, design and conduct an experiment or a series of experiments that demonstrate their understanding of the mathematical methods and processes involved.

PO-4: Scientific Communication Skills: Imbibe effective mathematical communication in both oral and written proof of theorems. Ability to show the importance of the subject as precursor to various scientific developments since the beginning of civilization.

PO-5: Project management and finance: Demonstrate knowledge and understanding of the Mathematical principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO-6: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern Mathematical and IT tools including prediction and modelling to Industrial activities with an understanding of the limitations.

PO-7: Self-Directed and Life-Long learning: Work independently, identify appropriate resources required for a project, and manage a project through to completion. Exhibit subject-specific transferable knowledge in Mathematics relevant to job trends and employment opportunities.

PO-8: Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

PO-9: Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these

assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO-10: Research Skills: Prepare students for pursuing research or careers in industry in concerned subject and allied fields. Capability to use appropriate software to solve various problems and to apply programming concepts of Python to various scientific investigations , problem solving and interpretation.

Program Specific Outcomes:
PSO-1: Have strong foundation in core areas of Mathematics, and be able to communicate Mathematics effectively.
PSO-2: Evaluate hypotheses, theories, methods and evidence within their proper contexts.
PSO-3: Solve complex problems by critical understanding, analysis and Synthesis.

SEMESTER-VII

Mathematics Theory Paper-19

Course Code:MTMAT-511/MTMAT-471/MTMAT-471R
Course Type: Theory
Course Name: Linear Algebra
Credits: 2
Hours: 30

Module-I

Unit 1: Vector Spaces and Linear Transformation [07 Hours]

1. Vector Spaces
2. Subspaces
3. Basis
4. Dimension
5. Linear Transformation

Unit 2: Linear Mappings and Matrices [08 Hours]

1. Linear Mappings
2. Quotient Spaces
3. Vector space of linear mappings
4. Linear mappings and matrices

Module-II

Unit 3: Reduction of matrices to canonical forms [07 Hours]

1. Eigenvalues and Eigenvectors
2. Triangularization of a matrix
3. Jordan Canonical form

Unit 4: Metric Vector spaces [08 Hours]

1. Bilinear forms
2. Symmetric bilinear forms
3. Quadratic forms
4. Hermitian forms

Recommended Book:

1 **First Course in Linear Algebra: P B Bhattacharya , S.K. Jain , S.R. Nagpaul (New age international Publishers)**.

i. Unit1: Chapter 4

ii. Unit 2: Chapter 5 (5.1 to 5.4)

iii. Unit 3: Chapter 6

iv. Unit 4: Chapter 7 (7.1 to 7.4)

Reference Book:

1 **University Algebra (Wiley Eastern Ltd)**,N.S. Gopalkrishnan .

2 **Linear Algebra and Its Applications**, Gilbert Strang

3 **Linear Algebra**, K. B. Datta.

4 **Elementary Linear Algebra**, Howard Anton.

5 **Schaum's Outline of Linear Algebra**, Seymour Lipschutz, Marc Lipson.

Course Outcomes:

CO1: Define Concepts of Vector Space, Subspace, linear dependence, basis, dimension.

CO2: Describe the concept of Linear Mappings.

CO3: Solve examples to find the inverse of linear transformation and Jordan canonical form.

CO4: Calculate coordinate vector , orthogonality, orthonormality, norm of vectors using formulas.

CO5: Solve Triangular and Diagonal Matrix using linear transformation.

CO6: Describe the concept of Bilinear Form.

SEMESTER-VII

Mathematics Theory Paper-20

Course Code:MTMAT-512/ MTMAT-472/MTMAT-472R
Course Type: Theory
Course Name: Group Theory
Credits: 2
Hours: 30

Module-I

Unit 1: Groups, Subgroups and Cyclic Groups [07 Hours]

1. Definition and Examples of Groups
2. Properties of Groups
3. Order of a finite group
4. Order of an element in group
5. Subgroups and Subgroup Tests
6. Cyclic Groups
7. Properties of Cyclic Groups
8. Classification of Subgroups of Cyclic Groups

Unit 2: Permutation Groups, Isomorphism [08 Hours]

1. Permutations Groups; Definition and notation
2. Cycles and Transpositions
3. Properties of Permutations
4. Even and odd permutations
5. Alternating Group
6. Isomorphism of Group
7. Properties of Isomorphisms
8. Cayley's Theorem
9. Automorphisms

Module-II

Unit 3:Cosets, and External Direct Product [05 Hours]

1. Cosets

2. Lagrange's Theorem and consequences
3. External Direct Products
4. Properties of External Direct Products

Unit 4: Normal Subgroups, Homomorphisms **[05 Hours]**

1. Normal Subgroups
2. Factor Groups
3. Application of Factor Groups
4. Internal Direct Products
5. Group Homomorphisms; Definition and examples
6. Properties of Homomorphisms; First Isomorphism Theorem

Unit 5: Fundamental Theorem and Sylow **[05 Hours]**

1. Fundamental Theorem of Finite Abelian Groups
2. Conjugacy Classes
3. Class Equation
4. The Sylow Theorems
5. Applications of sylow theorems

Recommended Book:

1 Joseph Gallian, Contemporary Abstract Algebra, 4th Edition, Narosa Publication

i. Unit1: Chapter 2,3,4
ii. Unit 2: Chapter 5,6
iii. Unit 3: Chapter 7,8
iv. Unit 4: Chapter 9,10
v. Unit 5: Chapter 11, 24

Reference Book:

1 Abstract Algebra, Thomas W. Hungerford

2 Abstract Algebra, David S. Dummit, Richard M. Foote.

3 A First Course in Abstract Algebra, John B. Fraleigh.

4 Topics in Algebra, I. N. Herstein.

Course Outcomes:

CO1: Define Group, Cyclic Group, Order of an element.

CO2: Use these definitions to check whether a given group is cyclic or not, and find a generator for a subgroup of a given order.

CO3: Define Permutation group, Even and Odd Permutation, Isomorphism of groups.

CO4: Find cosets of subsets of a group and define External Direct Product.

CO5: Define and find Normal subgroups of a group and Factor groups.

CO6: State and prove Fundamental Theorem of Finite abelian Group and finite conjugacy classes.

SEMESTER-VII

Mathematics Theory Paper-21

Course Code:MTMAT-513/MTMAT-473/MTMAT-473R
Course Type: Theory
Course Name: Advanced Calculus
Credits: 2
Hours: 30

Module-I

Unit 1: Differential Calculus of Scalar and Vector Fields [08 Hours]

1. The derivative of a scalar field with respect to a vector
2. Directional derivatives
3. partial derivatives
4. Partial derivatives of higher order
5. Inverse function theorem and Implicit Function theorem .
6. Directional derivatives and continuity
7. The total derivatives
8. The gradient of a scalar field

Unit 2: Line Integrals and Surface integral [07 Hours]

1. Paths and line integrals, Other notations for line integrals
2. Basic properties of line integrals
3. The concept of work as a line integral
4. Line integrals with respect to arc length
5. Applications of line integrals
6. Open connected sets
7. Independence of the path
8. The first and second fundamental theorem of calculus for line integral

Module-II

Unit 3: Line Integrals and Surface integral [07 Hours]

1. Surface integrals; Change of parametric representation
2. The theorem of Stokes

3. Curl and divergence of a vector field
4. Properties of curl and divergence
5. The divergence theorem (Gauss' theorem)
6. Application of divergence theorem

Unit 4: Multiple Integrals **[08 Hours]**

1. Double integrals, Application to area and Volume
2. Green's theorem in the plane; Some Application of Green's Theorem
3. Change of variables in double integral;,Trasformation formula
4. Change of variables in an n-fold integrals

Recommended Book:

1 Calculus Volume II (Second Edition), Tom M. Apostol.

Reference Book:

1 Mathematical Analysis Second Edition, Tom M.Apostol (Addison -Wesley Publishing Company)

2 Advanced Calculus, Patrick M. Fitzpatrick.

3 Advanced Calculus, David V. Widder.

4 Advanced Calculus, Kaplan and Friedman.

5 Advanced Calculus: A Geometric View, James J. Callahan.

Course Outcomes:

CO1: Describe the basic concept of directional derivative and partial derivatives.

CO2: Solve example to find directional derivative, check continuity of function

CO3: Explain the concept of line integral and application of line integral.

CO4: Explain parametric representation of surface integral, solve examples.

CO5: State divergence theorem and it's application and examples.

CO6: Solve example of double integrals.

SEMESTER-VII

Mathematics Theory Paper-22

Course Code:MTMAT-514/MTMAT-474/MTMAT-474R
Course Type: Theory
Course Name: Ordinary Differential Equations
Credits: 2 **Hours: 30**

Module-I

Unit 1: Linear Differential equations with constant coefficients

[05 Hours]

1. Linear Differential Equation with constant coefficients
2. To find complementary function(C.F.) of a given function and its working.
3. Particular Integral
4. General Methods of getting Particular Integral

Unit 2: Linear equations with variable coefficients

[10 Hours]

1. Second order homogeneous equations
2. Initial value problems for second order homogeneous equation
3. Linear Dependence and Independence
4. Wronskian and Linear Independence
5. Reduction of order of homogeneous equation
6. Homogeneous equation with analytic coefficient

Module-II

Unit 3: Linear Equations with regular singular points

[08 Hours]

1. Euler equation
2. Second order equation with regular singular points
3. Bessel's equation

Unit 4: Existence and uniqueness of solutions to first order equation

[07 Hours]

1. Equations with variables separated
2. Exact equations
3. Lipschitz condition
4. Approximation to and uniqueness of solutions

Recommended Book:

1 An Introduction to Ordinary Differential Equations, E. A. Coddington, (Prentice- Hall).

Reference Book:

1 Differential Equations, G. F. Simmons and S. G. Krantz, (Tata McGraw-Hill).

2 Ordinary Differential Equations, Vladimir I. Arnold.

3 Ordinary Differential Equations, William A. Adkins, Mark G. Davidson

4 A Textbook on Ordinary Differential Equations, Shair Ahmad, Antonio Ambrosetti.

5 Ordinary Differential Equations: Basics and Beyond, David G. Schaeffer, John W. Cain.

Course Outcomes:

CO1: Define differential equation, ordinary differential equation, degree, order of DE.

CO2: Second order and n^{th} order DE with variable coefficient, reduction of order method.

CO3: Can find Legendre polynomials, can identify and solve Bessel's equation, legendre equation.

CO4: Can identify and find solution to Euler's Equation, can identify regular singular, ordinary, singular point, indicial equation.

CO5: Solve DE by variable separable method, can solve exact DE By finding integrating factor.

CO6: Lipschitz condition and constant

SEMESTER-VII

Mathematics Theory Paper-21

Course Code:MTMAT-515/MTMAT-475/MTMAT-475R
Course Type: Theory
Course Name: Financial Mathematics - I
Credits: 2
Hours: 30

Module-I

Unit 1: Basic Concepts [05 Hours]

1. Arbitrage
2. Return and Interest.
3. The Time Value Of Money
4. Bonds , Shares And Indices
5. Models And Assumptions

Unit 2: Deterministic Cash Flows [10 Hours]

1. Net Present Value
2. Internal Rate of Return
3. A Comparison of IRR and NPV
4. Bonds: Price and Yield
5. Clean and Dirty Price
6. Price Yield Curves
7. Duration
8. Term Structure of Interest Rates
9. Immunisation
10. Convexity
11. Callable Bonds

Module-II

Unit 3: Random Cash Flows [08 Hours]

1. Random Returns
2. Portfolio Diagrams And Efficiency
3. Feasible Set

4. Markowitz Model
5. Capital Asset Pricing Model
6. Diversification
7. CAPM as a rising formula
8. Numerical Technique

Unit 4: Forwards And Futures [07 Hours]

1. Forwards and Futures
2. Forwards and Futures Price
3. Value of A Futures Contract
4. Method of Replicating Portfolios
5. Hedging with Futures
6. Currency Futures
7. Stock Index Futures

Recommended Book:

1 **The Calculus Of Finance - Amber Habib (Mathematical Sciences Foundation New Delhi)**

Reference Book:

1 **Financial Mathematics: A Comprehensive Treatment in Continuous Time**, Giuseppe Campolieti, Roman N. Makarov.

2 **Analytical Finance: The Mathematics of Interest Rate Derivatives, Markets, Risk and Valuation**, Jan R. M. Röman.

3 **An Introduction to the Mathematics of Financial Derivatives**, Salih N. Neftci.

4 **Mathematical Finance**, Ernst Eberlein, Jan Kallsen.

Course Outcomes:

CO1: Describe Arbitrage

CO2: Can find Return And Interest

CO3: Describe Bonds , Shares And Indices

CO4: Describe Net Present Value

CO5: Can find Price Yield Curves r.

CO6: Describe Immunisation

SEMESTER-VII

Mathematics Practical Paper-9

Course Code:MTMAP-516/ MTMAP-476/ MTMAP-476R
Course Type: Practical
Course Name: Practical on Linear Algebra and Group Theory
Credits: 2
Practicals: 12

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1. **Practical No.1:** Vector spaces, Subspaces
2. **Practical No.2:** Basis and Dimension
3. **Practical No.3:** Linear Mappings
4. **Practical No.4:** Eigenvalues and Eigenvectors
5. **Practical No.5:** Triangularization and Jordan Canonical form
6. **Practical No.6:** Bilinear form and Quadratic forms
7. **Practical No.7:** Groups, Subgroups and Cyclic Groups
8. **Practical No.8:** Permutation Groups
9. **Practical No.9:** Cosets, Lagrange's Theorem and External Direct Product
10. **Practical No.10:** Homomorphism and Isomorphism
11. **Practical No.11:** Normal Subgroups
12. **Practical No.12:** Fundamental Theorem of Finite Abelian group and Sylow Theorem

Recommended Book:

1 First Course in Linear Algebra: P B Bhattacharya , S.K. Jain , S.R. Nagpaul (New age international Publishers)

2 Joseph Gallian, Contemporary Abstract Algebra, 4th Edition, Narosa Publication

Course Outcomes:

CO1: Solve problems related to vector spaces, Subspaces.

CO2: Solve problems related to Linear Mappings.

CO3: Use appropriate method to find eigen values and eigen vectors.

CO4: Find which groups are Cyclic Groups and which are Normal Subgroupsn.

CO5: Find even and odd permutations and Isomorphic groups.

CO6: Find cosets of subsets of a group and define External Direct Product.

SEMESTER-VII

Mathematics Practical Paper-10

Course Code: MTMAP-517/MTMAP-477/MTMAP-477R
Course Type: Practical
Course Name: Practical on Advanced Calculus and Financial Mathematics-I
Credits: 2
Practicals: 12

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1. **Practical No.1:** Directional Derivatives
2. **Practical No.2:** line integral
3. **Practical No.3:** Surface integral
4. **Practical No.4:** Divergence theorem
5. **Practical No.5:** Multiple integral I
6. **Practical No.6:** Multiple integral II
7. **Practical No.7:** Arbitrage, Return and Interest
8. **Practical No.8:** Price and Yield
9. **Practical No.9:** Duration
10. **Practical No.10:** Convexity and Callable Bonds
11. **Practical No.11:** Random Cash Flows
12. **Practical No.12:** Forwards And Futures

Recommended Book:

1 First Course in Linear Algebra: P B Bhattacharya , S.K. Jain , S.R. Nagpaul (New age international Publishers)

2 The Calculus Of Finance - Amber Habib (Mathematical Sciences Foundation New Delhi)

Course Outcomes:

CO1: Solve Examples on line integrals and it's Applications.

CO2: Describe the Parametric representation of surface integral, solve examples.

CO3: Explain the concept of transformation formula and solve examples.

CO4: Describe Arbitrage.

CO5: Can find Return and Interest.

CO6: Describe Immunisation.

SEMESTER-VII

Mathematics Elective Theory Paper-5

Course Code: MTMET-511A/MTMET-471A/MTMET-471AR
Course Type: Theory
Course Name: Python Programming
Credits: 2
Hours: 30

Module-I

Unit 1: Conditional Statements [05 Hours]

1. if, if-else, and if-elif-else constructs
2. The if-elif-else Ladder
3. Logical Operators
4. The Ternary Operator
5. The get Construct
6. Examples

Unit 2: Looping [03 Hours]

1. While
2. Patterns
3. Nesting and Applications of Loops in Lists

Unit 3: Functions [03 Hours]

1. Features of a functions: Modular Programming; Reusability of Code, Manageability
2. Basic Terminology: Name of Functions; Arguments; Return Value
3. Definition and Invocation: Working
4. Type of Functions: Advantage of Arguments

Unit 4: Iterations, Generators, and Comprehensions [04 Hours]

1. The Power of "For"
2. Iterators
3. Defining an Iterable Object
4. Generators
5. Comprehensions

Module-II

Unit 5: File Handling [04 Hours]

1. The File Handling Mechanism
2. The Open Function and File Access Modes
3. Python Functions for File Handling: The Essential Ones; The OS Methods; Miscellaneous Functions and File Attributes
4. Command Line Arguments
5. Implementation and Illustrations

Unit 6: Strings [03 Hours]

1. The Use of "For" and "While"
2. String Operators: The Concatenation Operator (+); The Replication Operator; The Membership Operator
3. Functions for String Handling: len(); Capitalize(); find(); count; Endswith(); Encode; Decode; Miscellaneous Function

Unit 7: Introduction to Object Oriented Paradigm [04 Hours]

1. Creating New Types
2. Attributes and Functions: Attributes; Functions
3. Elements of Object- Oriented Programming: Class; Object; Encapsulation; Data Hiding
4. Inheritance; Polymorphism; Reusability

Unit 8: Classes and Objects [04 Hours]

1. Defining a Class
2. Creating an Object
3. Scope of Data Members
4. Nesting
5. Constructor
6. Constructor Overloading
7. Destructors

Recommended Book:

1 **Python Basics: A Self-Teaching Introduction**, H. Bhasin

Reference Book:

1 **Core Python Programming**, Wesley J. Chun

2 **Python Crash Course**, Eric Matthes

3 **Automate the Boring Stuff with Python**, Al Sweigart.

4 **Think Python: How to Think Like a Computer Scientist**, Allen B. Downey.

Course Outcomes:

CO1: Define and understand the terms strings, tuple, list.

CO2: Interpret the fundamental Python syntax and semantics and be fluent in the use of Python control flow statements.

CO3: Express proficiency in the handling of strings and functions

CO4: Determine the methods to create and manipulate Python programs by utilizing the data structures like lists, dictionaries, tuples and sets.

CO5: Describe the concept of classes and objects.

CO6: Implement Conditionals and Loops for Python Programs.

SEMESTER-VII

Mathematics Elective Practical Paper-5

Course Code: MTMEP-511B/MTMEP-471B/MTMEP-471BR
Course Type: Practical
Practical on Python Programming
Credits: 2
Practicals: 12

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1. **Practical No.1:** Conditional Statements
2. **Practical No.2:** Looping
3. **Practical No.3:** Strings
4. **Practical No.4:** File Handling
5. **Practical No.5:** Functions
6. **Practical No.6:** Iterations, Generators, and Comprehensions
7. **Practical No.7:** Iterations, Generators, and Comprehensions
8. **Practical No.8:** Classes and Objects
9. **Practical No.9:** Object Oriented Paradigm
10. **Practical No.10:** List and tuples
11. **Practical No.11:** AP and GP using generators
12. **Practical No.12:** AP and GP using Loop

Recommended Book:

1 Python Basics by H. Bhasin

Reference Book:

1 Core Python Programming, Wesley J. Chun

2 Python Crash Course, Eric Matthes

3 Automate the Boring Stuff with Python, Al Sweigart.

4 Think Python: How to Think Like a Computer Scientist, Allen B. Downey.

Course Outcomes:

CO1: Define and understand the terms strings, tuple, list.

CO2: Interpret the fundamental Python syntax and semantics and be fluent in the use of Python control flow statements.

CO3: Express proficiency in the handling of strings and functions.

CO4: Determine the methods to create and manipulate Python programs by utilizing the data structures like lists, dictionaries, tuples and sets.

CO5: Describe the concept of classes and objects.

CO6: Implement Conditionals and Loops for Python Programs.

SEMESTER-VII

Mathematics Elective Theory Paper-6

Course Code:MTMET-512A/ MTMET-472A/ MTMET-472AR
Course Type: Theory
Course Name: Dynamical System
Credits: 2
Hours: 30

Module-I

Unit 1: Eigenvalues and Eigenvectors [05 Hours]

1. Eigenvalues and Eigenvectors
2. Diagonalisation (matrices with real and distinct eigenvalues)

Unit 2:First-Order Equations and Planar Linear Systems [10 Hours]

1. The Simplest Example
2. The Logistic Population Model
3. Second-Order Differential Equations
4. Planar Systems
5. Preliminaries from Algebra
6. Planar Linear Systems
7. Eigenvalues and Eigenvectors
8. Solving Linear Systems
9. The Linearity Principle

Module-II

Unit 3: Phase Portraits for Planar Systems [07 Hours]

1. Real Distinct Eigenvalues
2. Complex Eigenvalues
3. Repeated Eigenvalues
4. Changing Coordinates

Unit 4: Classification of Planar Systems and Exponential of a matrix

[08 Hours]

1. 1.1The Trace-Determinant Plane
2. Exponential of a matrix
3. Dynamical classification
4. Exploration: 3D parameter space

Recommended Book:

1 Differential Equations, Dynamical Systems, and an Introduction to Chaos, Morris W. Hirsch, Stephen Smale, Robert L. Devaney

Reference Book:

1 Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering, Steven H. Strogatz.

2 Differential Equations and Dynamical Systems, Lawrence Perko.

3 Introduction to Applied Nonlinear Dynamical Systems and Chaos, Stephen Wiggins.

4 Dynamical Systems: An Introduction with Applications in Economics and Biology, Shlomo Sternberg.

Course Outcomes:

CO1: Solve problems related to Eigenvalues and Eigenvectors.

CO2: Use Second-Order Differential Equations to solve systems.

CO3: Use Linearity principle to solve the systems.

CO4: Solve problems related to phase portrait for linear systems.

CO5: Use Dynamical classifications and study 3D parameter space.

CO6: To study Higher Dimensional Linear Algebra and solve problems related to eigen values and eigenvectors.

SEMESTER-VII

Mathematics Elective Practical Paper-6

Course Code: MTMEP-472B/MTMEP-472B/MTMEP-472BR
Course Type: Practical
Practical on Dynamical System
Credits: 2
Practicals: 12

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1. **Practical No.1:** Eigenvalues and Eigenvectors
2. **Practical No.2:** Second-Order Differential Equations
3. **Practical No.3:** Planar Systems
4. **Practical No.4:** Solutions of Linear Systems
5. **Practical No.5:** Phase Portraits with Real Distinct Eigenvalues
6. **Practical No.6:** Phase Portraits for Planar Systems with Complex Eigenvalues
7. **Practical No.7:** Exponential of a matrix
8. **Practical No.8:** Dynamical classification
9. **Practical No.9:** Exploration: 3D parameter space
10. **Practical No.10:** Higher Dimensional Linear Algebra (Eigen values and Eigen vectors)
11. **Practical No.11:** Dynamical classification
12. **Practical No.12:** Diagonalization (matrices with real and distinct eigenvalues)

Recommended Book:

1 Differential Equations, Dynamical Systems, and an Introduction to Chaos, Morris W. Hirsch, Stephen Smale, Robert L. Devaney

Reference Book:

1 Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering, Steven H. Strogatz.

2 Differential Equations and Dynamical Systems, Lawrence Perko.

3 Introduction to Applied Nonlinear Dynamical Systems and Chaos, Stephen Wiggins.

4 Dynamical Systems: An Introduction with Applications in Economics and Biology, Shlomo Sternberg.

Course Outcomes:

CO1: Solve problems related to Eigenvalues and Eigenvectors.

CO2: Use Second-Order Differential Equations to solve systems .

CO3: Use Linearity principle to solve the systems.

CO4: Solve problems related to phase portrait for linear systems.

CO5: Use Dynamical classifications and study 3D parameter space.

CO6: To study Higher Dimensional Linear Algebra and solve problems related to eigen values and eigenvectors.

SEMESTER-VII

Mathematics Research Theory Paper

Course Code: MTRMT-511/MTRMT-471/MTRMT-471R
Course Type: Theory
Course Name: Research Methodology
Credits: 2
Hours: 30

Module-I

Unit 1: Foundations of Research [05 Hours]

1. Meaning, Objectives and types of Research
2. Research Approaches, Significance of Research
3. Research and scientific methods, Research process, Criteria for Good Research
4. Research Problem Identification, Techniques involved in Defining a Problem. Writing of Proofs, quantifiers etc

Unit 2: Research Design [05 Hours]

1. Meaning and need of Research Design, features of good Design, Important concepts related to Good Design
2. Different Research Designs, Basic principles of experimental Designs
3. Analysis of Literature Review – Primary and Secondary Sources
4. Web sources for critical Literature Review such as MathSciNet, ZMATH, Scop-us, Web of Science
5. reviewing literature and identifying research gaps

Unit 3: Research Methods [05 Hours]

1. Scientific methods, Logical Methods: Deductive, Inductive, logical methods
2. Quantitative research methods and Qualitative research methods
3. Data Collection Techniques, Surveys and questionnaires, Interviews and focus groups, Observations and case studies
4. Experimental methods
5. Statistical analysis techniques in mathematics, Qualitative data analysis methods, Visualization and interpretation of results

Module-II

Unit 4: Research Writing and Presentation [09 Hours]

1. Scientific/ technical Writing Structure and Components

2. Preparing Research papers for journals, Seminars and Conferences – Design of paper using TEMPLATE
3. Calculations of Impact factor of a journal, citation Index, ISBN and ISSN
4. Preparation of Project Proposal – Time frame and work plan – Budget and Justification – Preparation and Publication of Research paper, Thesis writing
5. Project Reports for various funding, Writing Statement of Purpose for PhD/Post Doc etc
6. Presenting research findings orally and visually, Research Collaboration and Communication, Collaborative research practices
7. Importance of Effective Communication,Effective communication in mathematical research, Participating in conferences and seminars

Unit 5: Research Ethics and Responsible Conduct [06 Hours]

1. Ethics and Ethical Issues – Ethical Committees
2. Commercialization, copy right, royalty, Intellectual Property rights and patent law
3. Track Related aspects of intellectual property Rights
4. Reproduction of published material, Plagiarism and software to detect plagiarism, Citation and Acknowledgement, Reproducibility and accountability

Recommended Book:

1 **Research Methodology: Methods and Techniques**, C. R. Kothari, Gaurav Garg.

Reference Book:

1 **Kothari, C.R. (2008), Research Methodology: Methods and Techniques. Second Edition. New Age International Publishers, New Delhi**

2 **Dilip Datta, LaTeX in 24 Hours, A Practical Guide for Scientific Writing, Springer**

3 **Eva O. L. Lantsoght, The A-Z of the PhD Trajectory -A Practical Guide for a Successful Journey, Springer Cham, 2018**

4 **The Craft of Research**, Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams

5 **Research Design: Qualitative, Quantitative, and Mixed Methods Approaches**, John W. Creswell, J. David Creswell

Course Outcomes:

CO1: Develop a comprehensive understanding of different research methodologies and their applications in mathematics.

CO2: Cultivate critical thinking and analytical skills necessary for identifying research problems and formulating research questions.

CO3: Provide practical experience in designing experiments, collecting and analyzing data, and interpreting research results.

CO4: Foster effective communication skills for presenting research findings orally and in written form.

CO5: Promote ethical research practices and awareness of responsible conduct in mathematical research.

SEMESTER-VII

Mathematics Research Practical Paper-6

Course Code: MTRMP-512/ MTRMP-472/MTRMP-472R
Course Type: Practical
Research Methodology
Credits: 2
Practicals: 12

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1. **Practical No.1:** Basic Latex, Beamer, Overleaf, Grammarly, QuillBot, ChatGPT, and SAGE Software installation
2. **Practical No.2:** Basic Algebraic Manipulations
3. **Practical No.3:** Calculus Computations: Differentiation, integration. Linear Algebra with SAGE
4. **Practical No.4:** Matrix operations, solving linear systems, eigenvalue calculations, Discrete Mathematics ,Combinatorics, graph theory with SAGE
5. **Practical No.5:** Matrix operations, solving linear systems, eigenvalue calculations, Discrete Mathematics ,Combinatorics, graph theory with SAGE
6. **Practical No.6:** Preparing Research papers for journals, Seminars and Conferences using Latex
7. **Practical No.7:** Different Research Designs using latex
8. **Practical No.8:** Data Collection Techniques using python
9. **Practical No.9:** Thesis writing using Latex
10. **Practical No.10:** Data types and Probability Analysis
11. **Practical No.11:** Simulation and Modeling
12. **Practical No.12:** Statistical Analysis

Recommended Book:

1 **Research Methodology: Methods and Techniques**, C. R. Kothari, Gaurav Garg.

Reference Book:

1 **Kothari, C.R. (2008), Research Methodology: Methods and Techniques. Second Edition. New Age International Publishers, New Delhi**

2 **Dilip Datta, LaTeX in 24 Hours, A Practical Guide for Scientific Writing, Springer**

3 **Eva O. L. Lantsoght, The A-Z of the PhD Trajectory -A Practical Guide for a Successful Journey, Springer Cham, 2018**

4 **The Craft of Research**, Wayne C. Booth, Gregory G. Colomb, Joseph M. Williams

5 **Research Design: Qualitative, Quantitative, and Mixed Methods Approaches**, John W. Creswell, J. David Creswell

Course Outcomes:

CO1: Develop a comprehensive understanding of different research methodologies and their applications in mathematics.

CO2: Cultivate critical thinking and analytical skills necessary for identifying research problems and formulating research questions.

CO3: Provide practical experience in designing experiments, collecting and analyzing data, and interpreting research results.

CO4: Foster effective communication skills for presenting research findings orally and in written form.

CO5: Promote ethical research practices and awareness of responsible conduct in mathematical research.

SEMESTER-VIII

Mathematics Theory Paper-24

Course Code: MTMAT-521/ MTMAT-481/MTMAT-481R
Course Type: Theory
Course Name: Number Theory
Credits: 2
Hours: 30

Module-I

Unit 1: Congruence [08 Hours]

1. Divisibility
2. Prime
3. The Binomial Theorem
4. Congruence
5. Solution of congruences
6. The Chinese Remainder Theorem

Unit 2: Quadratic Reciprocity and Quadratic Forms [07 Hours]

1. Quadratic Residues
2. Quadratic Reciprocity
3. The Jacobi symbol

Module-II

Unit 3: :Some Functions of Number Theory [08 Hours]

1. Greatest Integer Function
2. Arithmetic Functions
3. The Mobius Inversion Formula

Unit 4: Algebraic Numbers [07 Hours]

1. Polynomials
2. Algebraic Numbers
3. Algebraic Number Fields
4. Algebraic Integers
5. Diophantine Equation

Recommended Book:

1 **Ivan Niven; Herbert Zuckerman; Hugh Montgomery: An Introduction to Theory of Numbers, John Wiley and Sons, 5th Edition**

(a) Unit 1 : Chapter 1 (Sec 1.2 to 1.4), Chapter 2 (Sec 2.1 to 2.3)

(b) Unit 2 : Chapter 3 (Sec 3.1 to 3.3)

(c) Unit 3 : Chapter 4 (Sec 4.1 to 4.3)

(d) Unit 4 : Chapter 9 (Sec 9.1 to 9.5)

Reference Book:

1 **Elementary Number Theory**, David M. Burton

2 **A Classical Introduction to Modern Number Theory**, Kenneth Ireland, Michael Rosen.

3 **Number Theory: An Introduction to Mathematics**, W. W. Rouse Ball, H. S. M. Coxeter.

4 **Elementary Number Theory and Its Applications**, Kenneth H. Rosen.

Course Outcomes:

CO1: Define divisibility, primes and Congruences.

CO2: Define Quadratic Residue modulo n, Legendre symbol and Jacobi Symbol.

CO3: State and Prove Quadratic Reciprocity.

CO4: Define different functions on Number Theory.

CO5: State and prove Mobius Inversion Formula using concept of Mobius mu Function.

CO6: Define and Identify Algebraic Numbers and Algebraic Integer.

SEMESTER-VIII

Mathematics Theory Paper-25

Course Code: MTMAT-522/ MTMAT-482/MTMAT-482R
Course Type: Theory
Course Name: Ring Theory
Credits: 2
Hours: 30

Module-I

Unit 1: Rings [07 Hours]

1. Terminology
2. Rings of continuous functions, Polynomial rings, Matrix rings
3. Special rings, Boolean rings, Direct products
4. Characteristics of ring

Unit 2: Ideals [08 Hours]

1. Definitions and Examples
2. Basic properties of ideals
3. Algebra of ideals
4. Quotient rings
5. Ideals in quotient rings

Module-II

Unit 3: Homomorphism of Rings [06 Hours]

1. Fundamental theorems
2. Endomorphism Rings
3. Field of Fractions, Prime fields

Unit 4: Factorization in Domains [9 Hours]

1. Division in Domains
2. Euclidean Domains
3. Principal Ideal Domains
4. Factorization Domains
5. Unique Factorization Domains
6. Eisenstein's Criterion

Recommended Book:

1 **Rings and Modules, 2nd Revised Edition**,C. Musili, Narosa Publishing House.

Reference Book:

1 **Contemporary Abstract Algebra, fourth edition**, Joseph.A.Gallian,Narosa Publishing House.

2 **Introduction to Ring Theory**, P. M. Cohn.

3 **Rings and Categories of Modules**, Frank W. Anderson, Kent R. Fuller.

4 **Introduction to Commutative Algebra**, Michael F. Atiyah, Ian G. Macdonald.

5 **Ring Theory**, K. R. Goodearl.

Course Outcomes:

CO1: Define the terms ring, subring, integral domain, Field, Different types of Rings, ideals.

CO2: Solve examples of ideals, prime, principal and maximal ideals.

CO3: Compare the concept of integral domain, Field.

CO4: Identify homomorphism, endomorphism between rings.

CO5: Illustrate theorems on UID, PID , factor ring and UFD.

CO6: Justify concepts in Ring theory by giving counter example.

SEMESTER-VIII

Mathematics Theory Paper-26

Course Code: MTMAT-523/ MTMAT-483/MTMAT-483R
Course Type: Theory
Course Name: Measure and Integration
Credits: 2
Hours: 30

Module-I

Unit 1: Lebesgue Measure [10 Hours]

1. Lebesgue Outer Measure
2. σ-algebra of Lebesgue Measurable sets.
3. Outer and Inner Approximation of Lebesgue Measurable Sets
4. Countable Additivity
5. Continuity
6. Borel-Cantelli Lemma
7. Non-measurable Set, Cantor Set, Cantor-Lebesgue Function

Unit 2: Lebesgue Measurable Functions [05 Hours]

1. Definition and algebra of Lebesgue Measurable Functions
2. Sequential Point wise Limits and Approximations by Simple Functions
3. Littlewoods's Three Principles
4. Egoroff's Theorem
5. Lusin's Theorem

Module-II

Unit 3: Differentiation and Integration [15 Hours]

1. Continuity of Monotone Functions
2. Lebesgue's Differentiation Theorem
3. Functions of Bounded Variation
4. Jordan's Theorem, Absolutely Continuous Functions
5. Integration of Derivatives
6. Differentiation of Indefinite Integral

Recommended Book:

1 **Real Analysis-Fourth Edition**, H. L. Royden, P. M. Fitzpatrick. Sections: Chapter 2, chapter 3, chapter 6.

Reference Book:

1 **Measure Theory and Integration**, M. M. Rao.

2 **Measure and Integration**, Satish Shirali, Harkrishan Lal Vasudeva.

3 **Measure, Integration and Real Analysis**, Sheldon Axler

4 **Measure and Integral: An Introduction to Real Analysis**, Richard L. Wheeden.

Course Outcomes:

CO1: Define Lebesgue measure, outer measure, Lebesque measurable Functions.

CO2: Describe cantor set, Non measurable set, cantor-lebesgue function, Borel- Cantelli's Lemma.

CO3: Extract result of Differentiation and Integrations.

CO4: Check sets and functions are measurable or not.

CO5: Calculate measure of countable sets, uncountable sets, intervals.

CO6: Explain Littlewood's Three Principles, Egoroff's Theorem theorem, Lusin's Theorem, jordan's theorem.

SEMESTER-VIII

Mathematics Theory Paper-27

Course Code: MTMAT-524/MTMAT-484/MTMAT-484R
Course Type: Theory
Course Name: Partial Differential Equations
Credits: 2
Hours: 30

Module-I

Unit 1: Introduction to partial differential equations of first Order [06 Hours]

1. Genesis of first order P.D.E
2. Compatible systems
3. Charpit's method
4. Jacobi's method
5. Non Linear first order P.D.E

Unit 2: Fundamental Concepts [09 Hours]

1. First order partial differential equations
2. Classification of Second Order P.D.E.
3. Canonical Forms, Canonical Form for Hyperbolic Equation , Canonical Form for Parabolic Equation , Canonical Form for Elliptic Equation
4. General Method to Finding CF of Reducible and Irreducible Non-homogeneous Linear P.D.E.

Module-II

Unit 3: Elptic And Parabolic Differential Equations [10 Hours]

1. Occurrence of the Laplace and Poisson Equations
2. Boundary Value Problems (BVPs)
3. Dirichlet Problem for a Rectangle
4. Occurrence of the Diffusion Equation and Elementary solution of the Diffusion Equation
5. Dirac Delta Function
6. Separation of Variables Method (with examples)

Unit 4: Hyperbolic Differential Equations [05 Hours]

1. Occurrence of the Wave Equation
2. Derivation of One-dimensional Wave Equation
3. Solution of One-dimensional Wave Equation by Canonical Reduction

Recommended Book:

1 An Elementary Course in Partial Differential Equations, T Amarnath ,Narosa Publication.

2 Introduction to Partial Differential Equations, K.Sankara Rao (Third Edition) PHI Learning Private Limited.

Reference Book:

1 Partial Differential Equations, Jürgen Jost.

2 Introduction to Partial Differential Equations, Peter J. Olver.

3 Essential Partial Differential Equations: Analytical and Computational Aspects, David F. Griffiths, John W. Dold, David J. Silvester.

4 Partial Differential Equations: Analytical and Numerical Methods, Mark S. Gockenbach.

Course Outcomes:

CO1: Define First and Second order P.D.E, Order,Degree,Linear P.D.E,GEnesis of first and Second order.

CO2: Explain Method of Linear P.D.E with constant coefficient.

CO3: Explain Compatible System for finding solution of P.D.E.

CO4: Classify Second order P.D.E. in Canonical form and Canonical form for Parabolic , Hyperbolic and Eliptic Equation.

CO5: Solve linear P.D.E using charpits and Jacobi's Method.

CO6: Solve wave equation , Heat equation using separation method.

SEMESTER-VIII

Mathematics Theory Paper-28

Course Code: MTMAT-525/MTMAT-485/MTMAT-485R
Course Type: Theory
Course Name: Integral Equations
Credits: 2
Hours: 30

Module-I

Unit 1: Introductory Concepts [09 Hours]

1. Definitions
2. Classification of Linear Integral Equations
3. Solution of an Integral Equation
4. Converting Volterra Equation to ODE
5. Converting IVP to Volterra Equation
6. Converting BVP to Fredholm Equation

Unit 2: Fredholm Integral Equations [06 Hours]

1. Introduction
2. The Decomposition Method
3. The Direct Computation Method
4. The Successive Approximation Method
5. The Method of Successive Substitutions
6. Comparison between Alternative Methods

Module-II

Unit 3: Volterra Integral Equations [09 Hours]

1. Introduction
2. The Decomposition Method
3. The Series Solution Method
4. Converting Volterra Equation to IVP
5. The Successive Approximation Method
6. The Method of Successive Substitutions
7. Comparison between Alternative Methods
8. Volterra Equation of the First Kind

Unit 4: Fredholm Integro-Differential Equations [06 Hours]

1. Introduction
2. Fredholm Integro-Differential Equations
3. The Direct Computation Method
4. The Adomian Decomposition Method

Recommended Book:

1 **A First Course In Integral Equations**,Abul-Majid Wazwaz, World Scientific Publications, 1997. Chapter-1 -4.

2 **Integral Equations and Boundary value problems**Dr. M.D. Raisinghania, S.Chand Publishing.

3 **Integral Equations**, Shanti Swarup , Shiv Raj Singh : Krishna's Educational Publishers,1942.

4 **Integral Equations: A Short Course**, L. G. Chambers

5 **Handbook of Integral Equations**, Andrei D. Polyanin, Alexander V. Manzhirov.

Course Outcomes:

CO1: Define integral equations and linear integral equations and their types.

CO2: Describe the convergence of integral equations.

CO3: Explain the Fredholm and Volterra integral equations.

CO4: Using Decomposition Method to solve the Fredholm and Volterra integral equations.

CO5: Explain the concept of Homogeneous Fredholm Equations.

CO6: Apply the Green's Function to solve the integral equations.

SEMESTER-VII

Mathematics Practical Paper-11

Course Code: MTMAP-526/MTMAP-486/MTMAP-486R
Course Type: Practical
Course Name: Practical on Number Theory and Ring Theory
Credits: 2
Practicals: 12

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1. **Practical No.1:** Divisibility
2. **Practical No.2:** Congruence
3. **Practical No.3:** Quadratic Reciprocity and Jacobi symbol
4. **Practical No.4:** Functions of Number Theory
5. **Practical No.5:** Algebraic Numbers
6. **Practical No.6:** Quadratic Fields
7. **Practical No.7:** Examples of different rings
8. **Practical No.8:** Ideals, prime, principal and maximal ideals
9. **Practical No.9:** Homomorphism and endomorphism between Rings
10. **Practical No.10:** Field of Fractions, Prime fields
11. **Practical No.11:** Euclidean Domains and PID
12. **Practical No.12:** FD, UFD and Eisenstein's Criterion

Recommended Book:

1 Ivan Niven; Herbert Zuckerman; Hugh Montgomery: An Introduction to Theory of Numbers, John Wiley and Sons, 5th Edition

2 Joseph Gallian, Contemporary Abstract Algebra, 4th Edition, Narosa Publication House

Course Outcomes:

CO1: Solve examples of ideals, prime, principal and maximal ideals.

CO2: Solve examples on homomorphism and endomorphism.

CO3: Identify irreducible or reducible polynomials , solve examples on PID,UFD.

CO4: Solve Congruence and find Quadratic Residue modulo n, Legendre symbol and Jacobi symbol values.

CO5: Find values of different Arithmetic functions of Number Theory for any Integer.

CO6: Identify different Algebraic numbers and Algebraic Integers.

SEMESTER-VIII

Mathematics Practical Paper-12

Course Code: MTMAP-527/MTMAP-487/MTMAP-487R
Course Type: Practical
Course Name: Practical on Measure & Integration and Partial Differential Equations
Credits: 2
Practicals: 12

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1. **Practical No.1:** Lebesgue Outer Measure
2. **Practical No.2:** Continuity and Borel-Cantelli Lemma
3. **Practical No.3:** Lebesgue Measurable Functions-I
4. **Practical No.4:** Lebesgue Measurable Functions-II
5. **Practical No.5:** Differentiation
6. **Practical No.6:** Integration
7. **Practical No.7:** First order P.D.E.
8. **Practical No.8:** Second order P.D.E.
9. **Practical No.9:** Finding CF
10. **Practical No.10:** Boundary Value Problems
11. **Practical No.11:** Separation of variables method
12. **Practical No.12:** Hyperbolic Differential Equation

Recommended Book:

1 Real Analysis-Fourth Edition, Authors: H. L. Royden, P. M. Fitzpatrick. Sections: Chapter 2, chapter 3, chapter 6

2 Introduction to Partial Differential Equations, K.Sankara Rao (Third Edition) PHI Learning Private Limited

3 An Elementary Course in Partial Differential Equations, T Amarnath ,Narosa Publication

Course Outcomes:

CO1: Calculate Lebesgue Measure, Outer Measure and Identify Lebesgue Measurable Functions.

CO2: Calculate measures of countable sets, uncountable sets and Intervals.

CO3: Check sets and functions are measurable or not.

CO4: Solve linear P.D.E..

CO5: Classify Second order P.D.E. in Canonical form and Canonical form for Parabolic , Hyperbolic, and Elliptic Equation.

CO6: Solve Boundary Value Problems.

SEMESTER-VIII

Mathematics Elective Theory Paper-7

Course Code: MTMET-521A/MTMET-481A/MTMET-481AR
Course Type: Theory
Course Name: Financial Mathematics II
Credits: 2
Hours: 30

Module-I

Unit 1: Stock Price Models [05 Hours]

1. Lognormal Model
2. Geometric Brownian Motion
3. Suitability of GBM for Stock Price
4. Binomial Tree Model

Unit 2: Options [10 Hours]

1. Call Options
2. Put Options
3. Put-Call Parity
4. Binomial Options Pricing Model
5. Pricing American Options
6. Factors Influencing Option Premiums
7. Options on Assets with Dividents
8. Dynamic Hedging
9. Risk-Neutral Valuation

Module-II

Unit 3: The Black – Scholes Model [10 Hours]

1. Risk – Neutral valuation
2. The Black-Scholes Formula
3. Options on Futures
4. Options on Assets with Dividends
5. Black-Scholes and BOPM
6. Implied Volatility

7. Dynamic Hedging
8. The Greeks
9. The Black-Scholes PDE
10. Speculating with Options

Unit 4: Value at Risk [05 Hours]

1. Definition of VaR
2. Linear Model
3. Quadratic Model
4. Monte Carlo Simulation
5. The Martingale

Recommended Book:

1 The Calculus of Finance – Amber Habib

Reference Book:

1 Financial Mathematics: A Comprehensive Treatment in Continuous Time, Giuseppe Campolieti, Roman N. Makarov.

2 Analytical Finance: The Mathematics of Interest Rate Derivatives, Markets, Risk and Valuation, Jan R. M. Röman.

3 An Introduction to the Mathematics of Financial Derivatives, Salih N. Neftci.

4 Mathematical Finance, Ernst Eberlein, Jan Kallsen.

Course Outcomes:

CO1: Define the Geometric Brownian Motion, The Black – Scholes Model, Value at Risk.

CO2: Describe Stock Price Models, The Black – Scholes Model

CO3: Explain the Lognormal Model.

CO4: Illustrate the Call options, Put options.

CO5: Explain the concept of VaR.

CO6: Describe the Black –Scholes Model.

SEMESTER-VIII

Elective Mathematics Practical Paper-7

Course Code: MTMEP-521B/MTMEP-481B/MTMEP-481BR
Course Type: Practical
Practical on Financial Mathematics-II
Credits: 2
Practicals: 12

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1. **Practical No.1:** Lognormal Model
2. **Practical No.2:** Geometric Brownian Motion
3. **Practical No.3:** Pure Endowment
4. **Practical No.4:** Types of Binomial Tree Model
5. **Practical No.5:** Options
6. **Practical No.6:** Options on Assets with Dividends
7. **Practical No.7:** The Black Scholes Formula
8. **Practical No.8:** Implied Volatility
9. **Practical No.9:** Linear Model
10. **Practical No.10:** Quadratic Model
11. **Practical No.11:** Monte Carlo Simulation
12. **Practical No.12:** Martingale

Recommended Book:

1 The Calculus of Finance – Amber Habib

Course Outcomes:

CO1: Define the Geometric Brownian Motion, The Black – Scholes Model, Value at Risk.

CO2: Describe Stock Price Models, The Black – Scholes Model.

CO3: Explain the Lognormal Model.

CO4: Illustrate the Call options, Put options.

CO5: Explain the concept of VaR.

CO6: Describe the Black –Scholes Model.

SEMESTER-VIII

Mathematics Elective Theory Paper-8

Course Code: MTMET-522A/MTMET-482A/MTMET-482AR
Course Type: Theory
Course Name: Advanced Complex Analysis **Credits: 2**
Hours: 30

Module-I

Unit 1: Complex Differentiability and Conformity [05 Hours]

1. Definition and Basic Properties
2. Polynomials and Rational Functions
3. Analytical Functions: Power Series
4. Cauchy- Riemann Equations
5. Review of Calculus of Two Real Variables eigenvalues)

Unit 2:Contour Integration [10 Hours]

1. Definition and Basic Properties
2. Existence of Primitives
3. Cauchy-Goursat Theorem
4. Cauchy's Theorem via Green's Theorem
5. Cauchy's Integral Formulae
6. Analyticity of Complex Differentiable Functions
7. A Global Implication: Liouville
8. Mean Value and Maximum Modulus

Module-II

Unit 3: Zeros and Poles [05 Hours]

1. Zeros of Holomorphic Functions
2. Open Mapping Theorem
3. Singularities
4. Laurent Series
5. Residues

Unit 4: Application to Evaluation of Definite Real Integrals [10 Hours]

1. Trigonometric Integrals
2. Improper Integrals
3. Jordan's Inequality

Recommended Book:

1 Basic Complex Analysis of One Variable,Anant R. Shastri, Macmillan Publishers India, 2010

Reference Book:

1 Complex Analysis, Elias M. Stein, Rami Shakarchi

2 Functions of One Complex Variable I, John B. Conway

3 Complex Analysis, Lars Ahlfors

4 Complex Made Simple, David C. Ullrich

Course Outcomes:

CO1: Define the Complex Differentiability and Conformity, Zeros and Poles.

CO2: Describe Analyticity of Complex Functions.

CO3: Explain Cauchy's Theorem via Green's Theorem and Cauchy's Integral Formulae.

CO4: Illustrate Contour Integration using Cauchy-Goursat Theorem.

CO5: Explain the concepts of Zeros, Poles and Singularity of Functions.

CO6: Explain Application to Evaluation of Definite Real Integrals.

SEMESTER-VIII

Mathematics Elective Practical Paper-8

Course Code: MTMEP-522B/MTMEP-482B/MTMEP-482BR
Course Type: Practical
Practical on Advanced Complex Analysis
Credits: 2
Practicals: 12

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1. **Practical No.1:** Polynomials and Rational Functions
2. **Practical No.2:** Analytical Functions: Power Series
3. **Practical No.3:** Cauchy- Riemann Equations
4. **Practical No.4:** Existence of Primitives and Cauchy-Goursat Theorem
5. **Practical No.5:** Cauchy's Theorem via Green's Theorem and Cauchy's Integral Formulae
6. **Practical No.6:** Analyticity of Complex Differentiable Functions
7. **Practical No.7:** Liouville Theorem and Mean Value and Maximum Modulus
8. **Practical No.8:** Zeros of Holomorphic Functions
9. **Practical No.9:** Open Mapping Theorem and Singularities
10. **Practical No.10:** Laurent Series and Residues
11. **Practical No.11:** Trigonometric Integrals and Improper Integrals
12. **Practical No.12:** Jordan's Inequality

Recommended Book:

1 Basic Complex Analysis of One Variable,Anant R. Shastri, Macmillan Publishers India, 2010

Reference Book:

1 Complex Analysis, Elias M. Stein, Rami Shakarchi

2 Functions of One Complex Variable I, John B. Conway

3 Complex Analysis, Lars Ahlfors

4 Complex Made Simple, David C. Ullrich

Course Outcomes:

CO1: Define the Complex Differentiability and Conformity, Zeros and Poles.

CO2: Describe Analyticity of Complex Functions.

CO3: Explain Cauchy's Theorem via Green's Theorem and Cauchy's Integral Formulae.

CO4: Illustrate Contour Integration using Cauchy-Goursat Theorem.

CO5: Explain the concepts of Zeros, Poles and Singularity of Functions.

CO6: Explain Application to Evaluation of Definite Real Integrals.